A REVIEW OF THE TRENTON FORMATION AND ITS PAST AND FUTURE PRODUCTION IN NORTHWESTERN OHIO

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by

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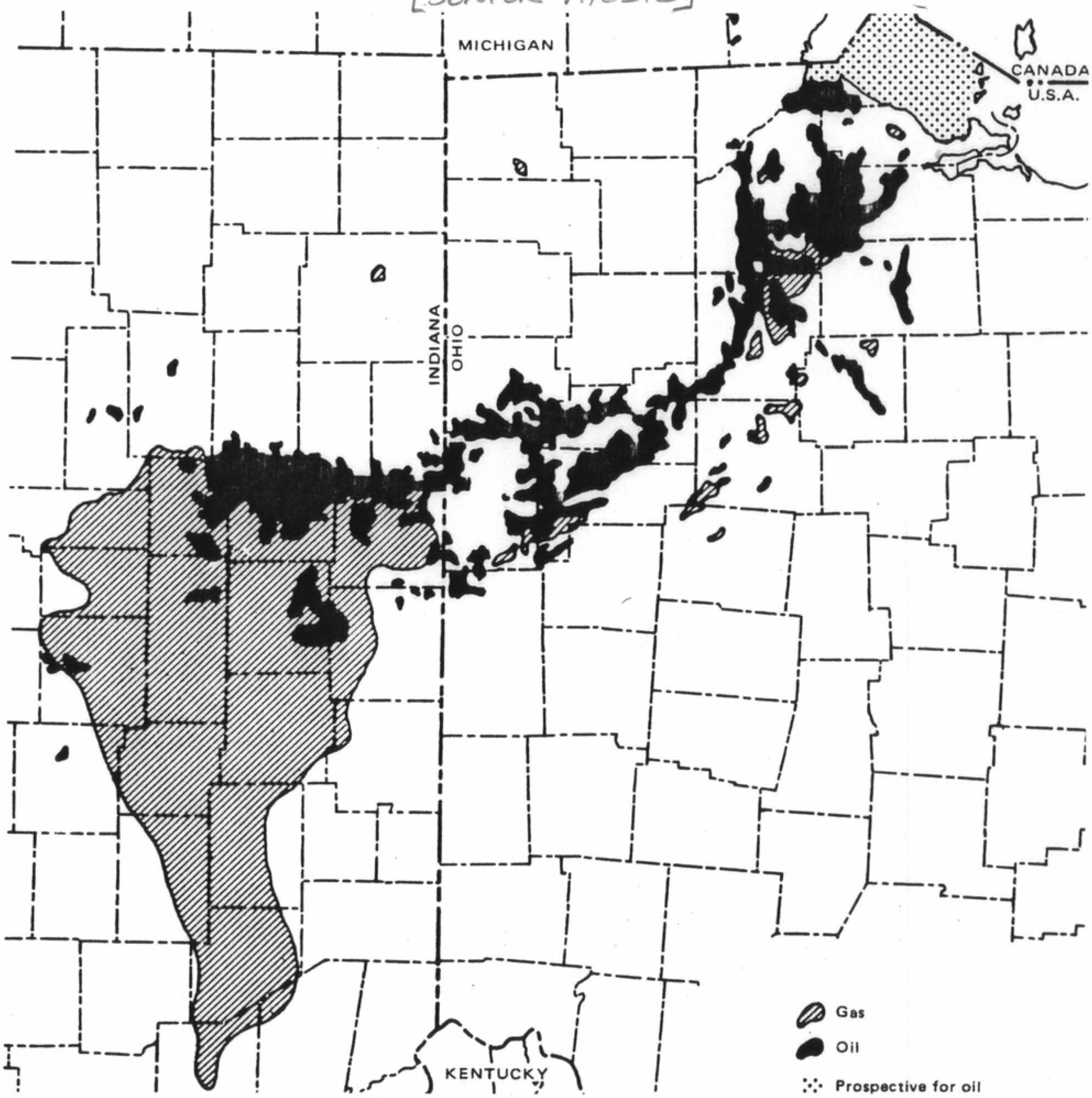
[SENIOR THESIS]



A REVIEW OF THE TRENTON FORMATION AND ITS PAST AND FUTURE PRODUCTION IN NORTHWESTERN OHIO

ABSTRACT

Beginning in the late 1800's in northwestern Ohio, discoveries of natural gas and later oil gradually revealed what today is known as the Lima-Indiana field, one of the largest ever in North America. The production of this field was initially quite strong. However, because gas rather than oil was the sought resource, and primative recovery techniques were used, it was short-lived. It is quite probable that a large percent of the oil remains, oil previously unprofitable to attain. Virtually all the production came from the Trenton Formation, an extensive limestone, locally dolotimized, creating porous zones capable of trapping hydrocarbons. Structural features and stratigraphy, along with porousity, contribute to the Trenton's reservoir characteristics. As energy and economic demands for oil and gas continue to climb, renewed production and increased recovery become more desireable and further detailed analysis of this generally abandoned area may be worthwhile.

INTRODUCTION

The production zones of the Lima-Indiana field will be our main concern, although it will be useful to note the geology of the surrounding areas as well. More specific information will highlight the productive territory within Ohio, and fig. 2 indicates counties within this area. Current production in this area is not completely absent, as small independent and noncommercial drilling projects continue. The Ohio Dept. of Natural Resources reported 60 new wells in the Trenton Formation in 1981, including 24 in Seneca, 13 in Van Wert, and 9 in Paulding Counties. A more detailed table is shown in fig. 1. Also, it might be noted that 5,585 wells in 1981 set the new record for total drilling operations in the state. After a review and re-evaluation of the past, and newly discovered areas, large-scale projects in the Trenton may become feasible.

SUMMARY OF NEW OIL AND GAS WELL DRILLING BY PRODUCING ZONES-1981

	Gas wells			Oil wells			Combination wells				Total producing wells				Dry holes				
Producing zones	No.	Mcfd	Ft	No.	Bo/d	Ft	No.	Mcfd	Bo/d	Ft	No.	Mcfd	Bo/d	Ft	No.	Ft	Total wells	Total ft	% Productive
Pennsylvanian (undifferentiated)	16	4,404	13,931	7	18	5,886	3	62	12	2,233	26	4,466	30	22,050	8	5,104	34	27,154	76.47
Upper Mississippian (undifferentiated)	4	830	6,716	1	1	770	6	241	76	9,002	11	1,071	77	16,488	0	0	11	16,488	100.00
Lower Mississippian (1st & 2nd Berea)	114	20,997	193,416	117	385	122,260	371	28,822	1,165	645,926	602	49,819	1,550	961,602	51	51,908	653	1,013,510	92.18
Devonian Ohio Shale	299	45,340	949,298	3	156	10,382	227	21,714	3,755	753,655	529	67,054	3,911	1,713,335	6	16,983	535	1,730,318	98.87
Devonian Gordon	72	7,154	179,476	2	24	4,711	80	11,117	493	200,345	154	18,271	517	384,532	2	4,801	156	389,333	98.71
Devonian "Big Lime"	2	535	7,626	0	0	0	0	0	0	0	2	535	0	7,626	0	0	2	7,626	100.00
Devonian Oriskany	5	1,460	18,285	0	0	0	5	1,942	125	18,129	10	3,402	125	36,414	0	0	10	36,414	100.00
Silurian Bass Island	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2,752	1	2,752	00.00
Silurian Newburg	3	1,825	7,551	0	0	0	1	45	6	4,901	4	1,870	6	12,452	1	4,630	5	17,082	80.00
Silurian Clinton-Medina	728	234,631	3,200,574	250	2,621	857,077	2,703	418,947	23,515	10,913,750	3,681	653,578	26,136	14,971,401	213	1,063,567	3,894	16,034,968	94.53
Upper Ordovician Cincinnatian	0	0	0	1	5	900	0	0	0	0	1	0	5	900	0	0	1	900	100.00
Lower Ordovician Trenton-Rose Run	13	1,285	46,375	7	78	10,060	19	2,077	97	54,238	39	3,362	175	110,673	30	80,214	69	190,887	56.52
Cambrian (undifferentiated)	0	0	0	6	62	18,986	4	410	153	15,353	10	410	215	34,339	40	126,081	50	160,420	20.00
Precambrian	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	9,879	4	9,879	00.00
Total	1,256	318,461	4,623,248	394	3,350	1,031,032	3,419	485,377	29,397	12,617,532	5,069	803,838	32,747	18,271,812	356	1,365,919	5,425	19,637,731	93.43

Source: Ohio Department of Natural Resources, Oil & Gas Division

Fig. 1

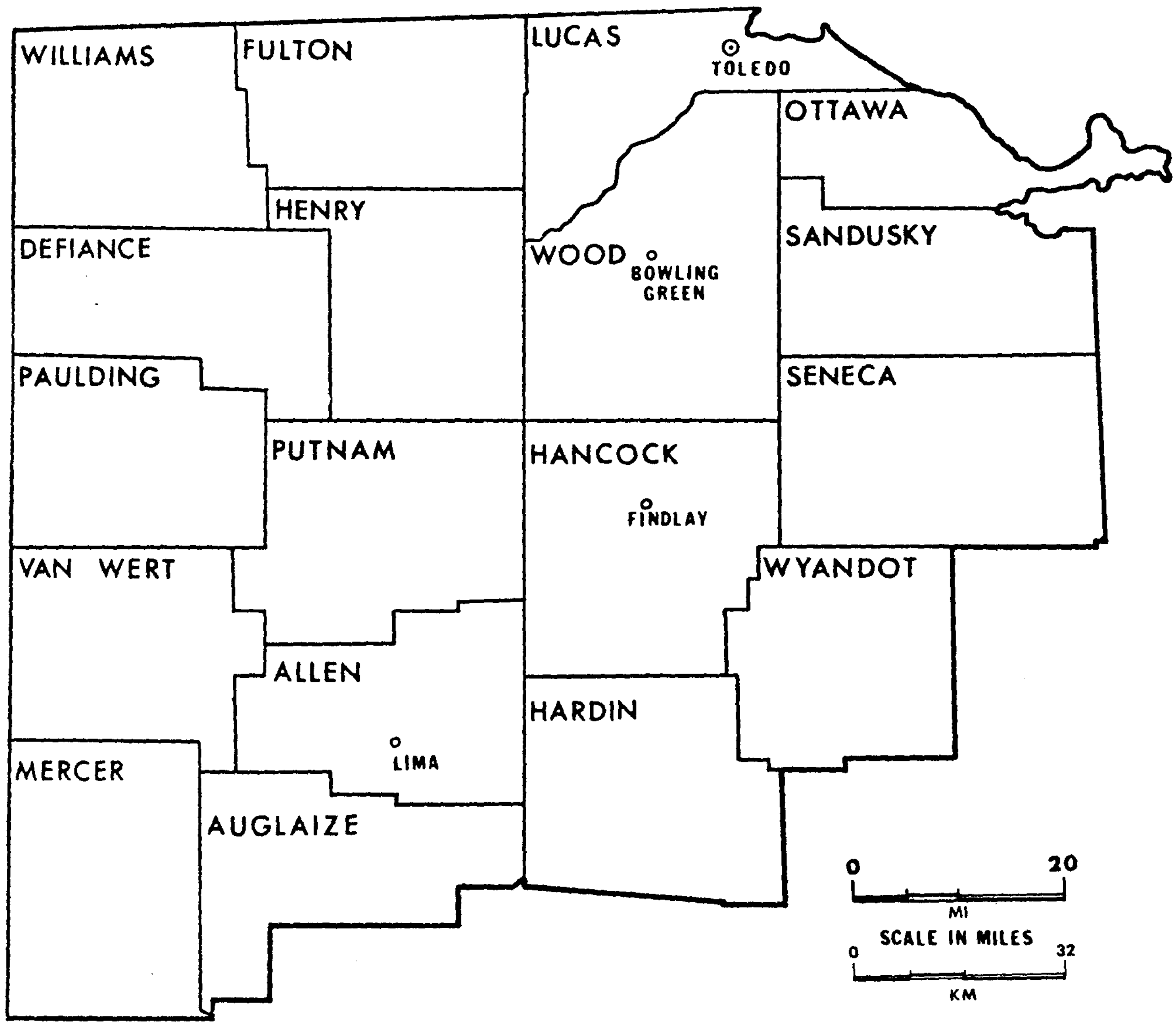

WILLIAMS
FULTON
LUCAS
TOLEDO
OTTAWA
HENRY
DEFIANCE
WOOD
BOWLING GREEN
SANDUSKY
PAULDING
SENECA
PUTNAM
HANCOCK
FINDLAY
VAN WERT
WYANDOT
ALLEN
HARDIN
LIMA
MERCER
AUGLAIZE
0
20
MI
SCALE IN MILES
0
32
KM

Fig. 2

OIL AND GAS HISTORY

As in all geologic ventures, the key to the present is the past. The historyof the gas discoveries of nearly 100 years ago, and the beginnings of the petroleum industry in northwestern Ohio are as follows.

Natural gas from the Trenton Formation was first discovered in this region in November, 1884, in Findlay, Ohio, Hancock Co., at the Karg well (Orton 1888). At that time gas was the valued commodity and any oil that was found was considered a nuisance. By 1885, uses for oil were more popular and oil production accompanied that of gas. Rich territories were found in Wood and Allen Counties, and production soon spread throughout the neighboring counties as well.

The area of production is shown in fig. 3, and remains nearly as it was in 1900. This includes a belt extending from Lucas and Ottawa Counties, southwest to VanWert and Mercer Counties, and further west into Indiana.

Orton (1888) reports several large gas wells with initial productions of 12 - 32 million cubic feet per day. Orton (1888) and Bownocker (1903) mention several large oil wells producing from 350 to 10,000 barrels per day. On the average, wells produced smaller amounts, and Buehner (1971) estimates 840 bbls/acre in Ohio, with maximums ranging from 1,000 to 9,000 bbls/acre, and 535 bbls/acre in Indiana.

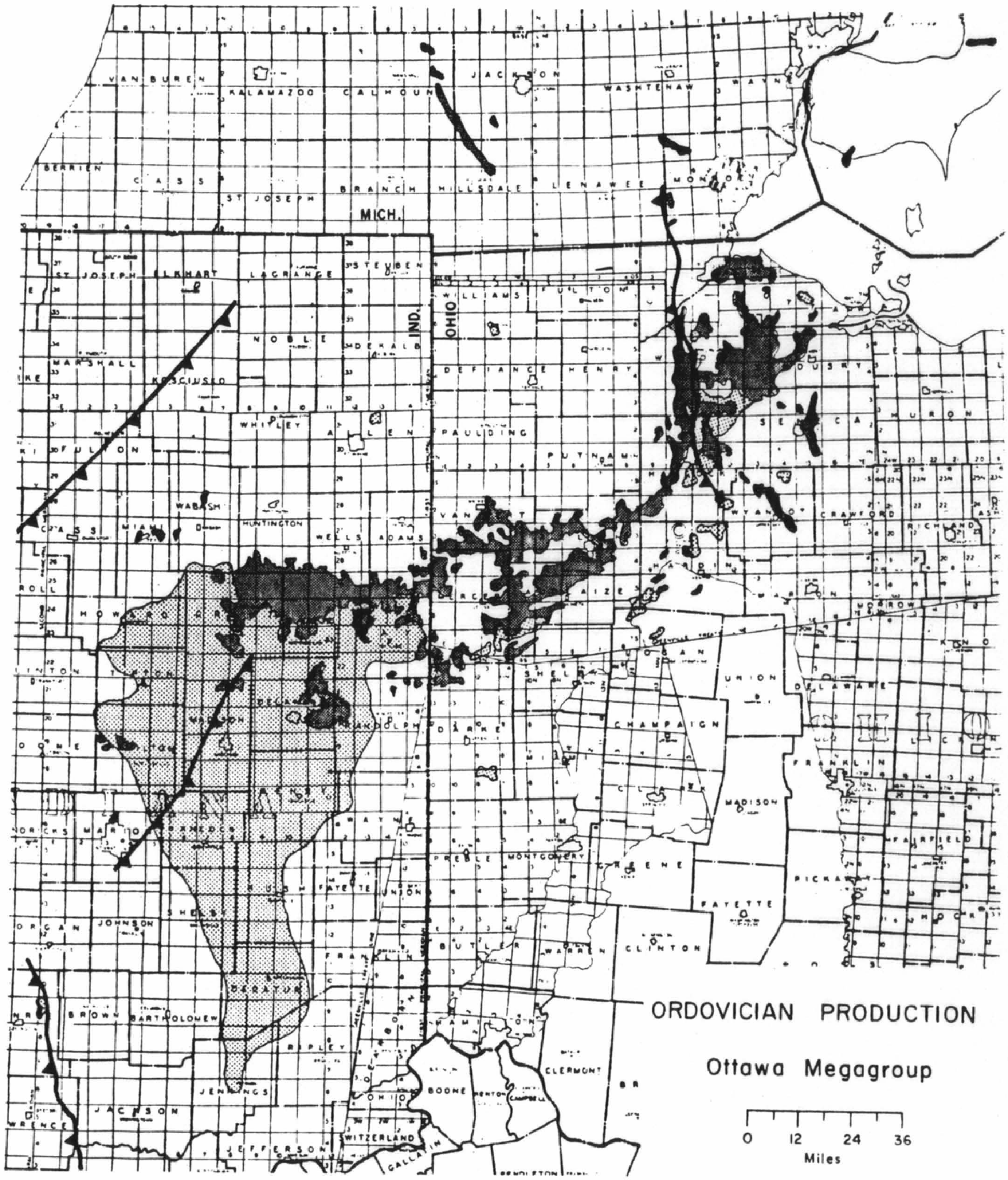

ORDOVICIAN PRODUCTION
Ottawa Megagroup
0 12 24 36
Miles
MICH.
IND.
OHIO

Fig. 3

Production noticeably increased from just over one million bbls/d in 1886 to nearly ten million bbls/d in 1888, (Bownocker, 1903) as local towns developed natural gas companies and distribution facilities for private heating as well as industrial uses, e.g., glass factories. Production peaked around 1896 at over 20 million bbls/d, and as quickly declined to almost ten million bbls/d in 1906, and almost one million bbls/d by 1934 (Alkire, 1951). Fig. 4 is a complete list of Trenton production from 1886 to 1939. Bownocker (1903) estimates a 12.5%/year decrease in production, lasting on the average for ten to twelve years.

This rather short-lived production was due to several causes. Being a cheap, seemingly limitless supply of fuel, it was rapidly used by local consumers and industry. Perhaps more important, recovery techniques were improper and inefficient, and sometimes uncontrolled. As gas was the chief concern of the drillers, its necessary driving pressures rapidly declined, making it increasingly difficult to bring up the vast amounts of oil, leaving a possibly large percent still in place. In addition, abandoned wells were frequently left unplugged, further retarding pressures.

Well records were not properly kept, and accurate production figures are unavailable. However, current total estimates of Trenton production from the Lima-Indiana field are 483 million bbls from 100,000 wells on 650,000 acres, 380 million bbls from Ohio areas alone (Buehner, 1971).

TRENTON OIL PRODUCTION IN NORTHWESTERN OHIO

Year		*Production (barrels)*	*Cumulative production (barrels)*
1886		1,064,025	1,064,025
1887		4,650,375	5,714,400
1888		9,682,683	15,397,083
1889		12,153,189	27,550,272
1890		15,014,882	42,565,154
1891		17,315,978	59,881,132
1892		15,169,507	75,050,639
1893		13,646,804	88,697,443
1894		13,607,844	102,305,287
1895		15,850,609	118,155,896
1896	PEAK	20,575,138	138,731,034
1897		18,682,677	157,413,711
1898		16,590,416	174,004,127
1899		16,377,174	190,381,301
1900		16,884,358	207,265,659
1901		16,176,293	223,441,952
1902		15,877,730	239,319,682
1903		14,893,853	254,213,535
1904		13,350,060	267,563,595
1905		11,329,924	278,893,519
1906		9,881,184	288,774,703
1907		7,993,057	296,767,760
1908		6,748,676	303,516,436
1909		5,915,357	309,431,793
1910		5,094,136	314,525,929
1911		4,535,875	319,061,804
1912		3,955,897	323,017,701
1913		3,817,043	326,834,744
1914		3,727,087	330,561,831
1915		3,393,833	333,955,664
1916		3,135,967	337,091,631
1917		2,910,861	340,002,492
1918		2,343,164	342,345,656
1919		2,514,000	344,859,656
1920		2,115,000	346,974,656
1921		2,137,000	349,116,656
1922		2,030,000	351,141,656
1923		2,154,000	353,295,656
1924		2,018,000	355,313,656
1925		1,940,000	357,253,656
1926		1,880,000	359,133,656
1927		1,709,000	360,842,656
1928		1,581,000	362,423,656
1929		1,484,000	363,907,656
1930		1,312,000	365,219,656
1931		1,115,000	366,334,656
1932		1,057,000	367,391,656
1933		1,026,000	368,417,656
1934		976,000	369,393,656
1935		907,000	370,300,656
1936		?	?
1937		627,000	?
1938		582,000	?
1939		Not available from 1939 on	375,000,000 estimated final cumulative production

Information compiled from *"Mineral Resources of the United States"* published by U.S. Geological Survey.

Fig. 4

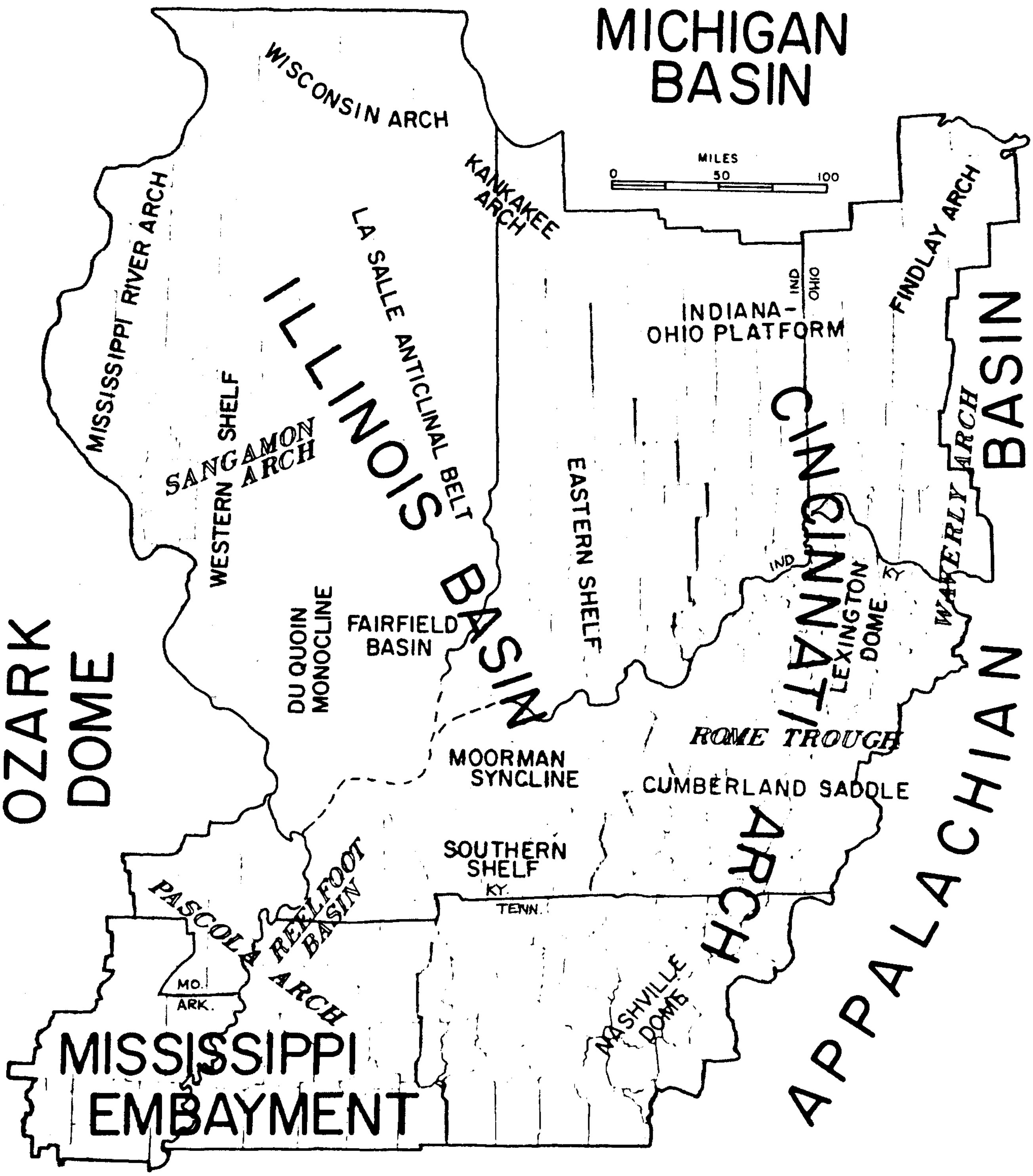
GENERAL STRATIGRAPHY AND HISTORY OF THE TRENTON

Production in the Lima-Indiana field centers from the Trenton Formation. This formation was named by Lardner Vanuxem in 1838 after the Trenton Falls in Oneida County, New York.(Vanuxem, 1838). The Trenton is a widespread carbonate sediment extending from New England to the Rocky Mountains, and from north of Hudson Bay to the southern Alleghanies in Alabama and Tennessee (Orton, 1888). It is mid-Ordovician in age, deposited during the Champlanian series. The oldest formation in this series, and a familiar reference point, in the St. Peter Sandstone, unconformable at its base where it overlies the lower Ordovician Canadian series. It is also unconformable above, where the Glenwood Shale overlies it. Conformable on top of the Glenwood lie the Black River and Trenton Limestones respectively. These carbonate deposits are covered by various shales of the Cincinnati series. A more detailed stratigraphy and geologic history will follow.

REGIONAL STRUCTURE

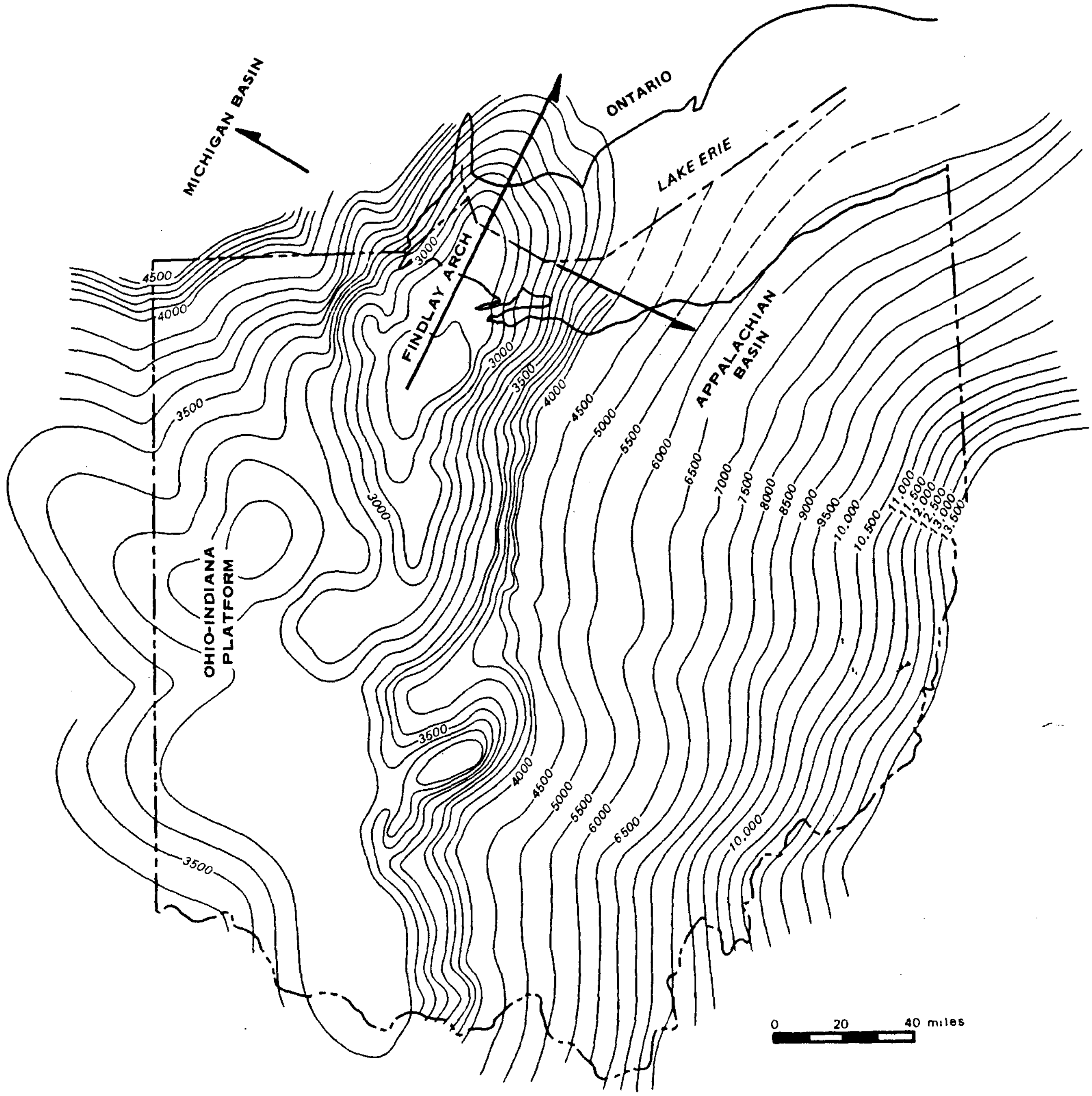
The strata in the subject area directly reflect the structural features present in what is part of the "Eastern Interior Region" (Buschback, 1971). A look at fig. 5 is a general map of these familiar features which include large arches, basins, domes, and localized faulting. Perhaps the most influential in the area of discussion is the nearby Cincinnati arch. Its axis strikes north-northeasterly, and extends from northern Indiana and the Michigan basin to Tennessee and the Mississippi embayment. The Cincinnati arch applies to the entire feature, its named and unnamed components. Northwestern Ohio lies on what is called the Indiana-Ohio platform and the adjoining Findlay arch. Here, the bedrock on the east limb of the arch is at relatively shallow depths, 2600 ft. (Buehner, 1971, p.35), and is covered by the fairly small sequence of Paleozoic rocks which include the Trenton Formation. Fig. 6 illustrates this. As one might expect, sediments thicken away from the arch on its limbs. Another important feature is the Bowling Green monocline with associated fractures and faulting, which extends northwest-southeast from Lucas, through Wood, and hancock, to Hardin Counties. Production has been exceptionally high in these areas.

A brief stratigraphic and geologic history will best review how these sediments were deposited the way they are, and how the structures in this area developed.



MICHIGAN BASIN
MILES
0
50
100
WISCONSIN ARCH
KANKAKEE ARCH
MISSISSIPPI RIVER ARCH
LA SALLE ANTICLINAL BELT
ILLINOIS BASIN
WESTERN SHELF
SANGAMON ARCH
FINDLAY ARCH
IND
OHIO
INDIANA-OHIO PLATFORM
CINCINNATI ARCH
BASIN
WAVERLY ARCH
EASTERN SHELF
IND
KY
LEXINGTON DOME
OZARK DOME
DU QUOIN MONOCLINE
FAIRFIELD BASIN
ROME TROUGH
MOORMAN SYNCLINE
CUMBERLAND SADDLE
APPALACHIAN
SOUTHERN SHELF
KY.
TENN.
PASCOLA ARCH
REELFOOT BASIN
MO.
ARK.
NASHVILLE DOME
MISSISSIPPI EMBAYMENT

Fig. 5



Depths to the Precambrian basement in Ohio, contour interval 500 feet

Fig. 6

STRATIGRAPHY AND GEOLOGIC HISTORY
(See stratigraphic column, Fig. 7)

The basement of the section in the subject area is the Grenville-aged (800-1000 m.y. old) metamorphic complex. It belongs to the Precambrian era, although it is sometimes referred to as Eocambrian. It consists of glaciated boulder deposits, intrusives, metamorphics, and some carbonate sequences. The carbonates are bituminous and could be source rocks for overlying reservoirs (Buehner, 1971). Plate tectonics were an influencing factor throughout this time, although to what extent is uncertain. A major unconformity covers these basement rocks.

The next mappable unit above the unconformity, the Potsdam supergroup, begins Paleozoic deposition and includes the Mt. Simon Sandstone, the Eau Claire Formation, and the Dresbach Sandstone in ascending order. These are mid-Cambrian in age and were deposited during the extensive rise in sea level that transgressed the craton throughout the Cambrian.

The Knox supergroup, which follows the Potsdam, includes the Franconia Sandstone and the Trempeal Dolomite, late Cambrian in age. By this time, epeiric seas covered much of the shallower craton and carbonate deposition began to dominate sands (Batten and Dott, 1981). These lower Ordovician deposits of the Canadian series include in ascending order, the Oneota Dolomite, the New Richmond Sandstone, and the

	System	Series	Stage	Group	Supergroup	Formation	General Thickness (Ft.)
Upper Paleozoic	Devonian			New Albany	Knobs		
						Ohio Sh.	
		Erian	Hamiltonian			Olentangy Sh.	15-30
				Onondaga	Hunton	Delaware Ls.	
		Ulsterian	Onondagan				
						Columbus Ls.	80-125
						Oriskany Ss.	0-40
	Silurian	Cayugan	Salinan	Cayuga		Tymochtee Fm.	
						Greenfield Dol.	
		Niagaran		Niagara		Lockport Dol.	135-335
						Niagara Ls.	
			Clinton			Clinton Ls.	21-100
		Alexandrian	Medinan	Albion			
						Medina Sh.	10-300
Lower Paleozoic	Upper Ordovician	Cincinnatian		Cincinnatian	Maquoketa	Queenston Sh.	
			Edenian			Eden Sh.	225-275
						Utica Sh.	50-370
						Cynthiana Fm.	
	Middle Ordovician	Champlainian		Trenton	Ottawa	Trenton Fm	155-225
				Platteville		Black River Ls.	375-475
				Ancell	Glenwood	Glenwood Sh. (Chazy)	10-40
					St. Peter Ss.	St. Peter Ss.	0-100
						Knox Unconformity	
	Lower Ordovician	Canadian		Prairie du Chien	Knox	Shakopee Dol.	300-1500
						New Richmond Ss.	0-100
						Oneota Dol.	300-800
	Upper Cambrian	St. Croixian	Trem.			Trempeal Dol.	
			Franconian			Franconia Ss.	200-600
				Coosta-naula		Dresbach Ss.	Avg. 720
			Dresbach-ian			Eau Claire Fm.	400-1000
					Pots-dam	Mt. Simon Ss.	0-1500
						Basement Unconformity	
Precambrian							
						Grenville Basement Complex	

Shakopee Dolomite. Throughout this time, continuing plate activity was affecting the emergence and submergence of the cratons, and regressive/transgressive phases continued as well. By the close of the Canadian, the region we are concerned with had become tilted to the south. The Kankakee arch had become evident in northern Indiana (Buschback, 1971), and the positive area separating the Appalachian and Illinois basins ran northerly through central Ohio, near what today is known as the Waverly arch (Woodward, 1961).

Following a retreat of the seas, a widespread unconformity was eroded across the previous Sauk sequence. (Sequences are groups of strata bounded by major unconformities.) Fig. 8 shows the surface of the "Knox unconformity". Maximum relief on this surface was 100 meters (Batten and Dott, 1981).

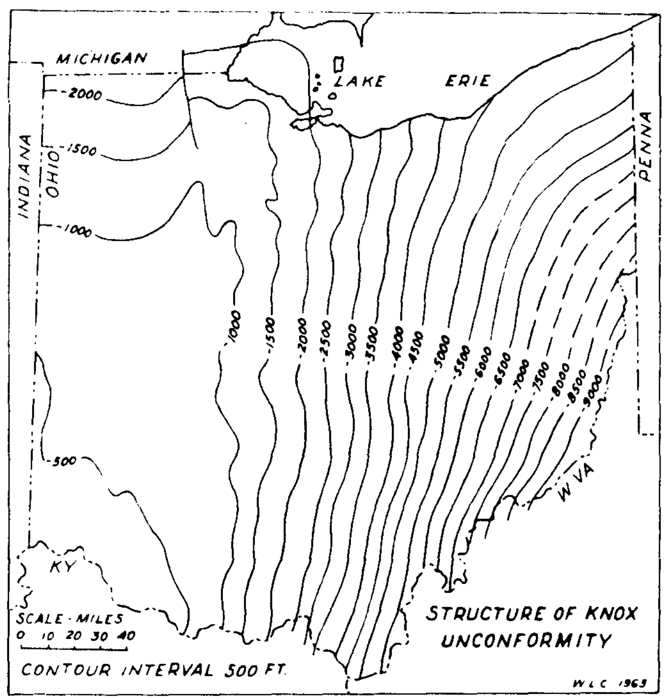


Fig. 8

The St. Peter Sandstone overlies the Knox supergroup. It is the basal unit of the Tippecanoe sequence and the Champlainian series. It was deposited during renewed transgression as is illustrated by fig. 9.

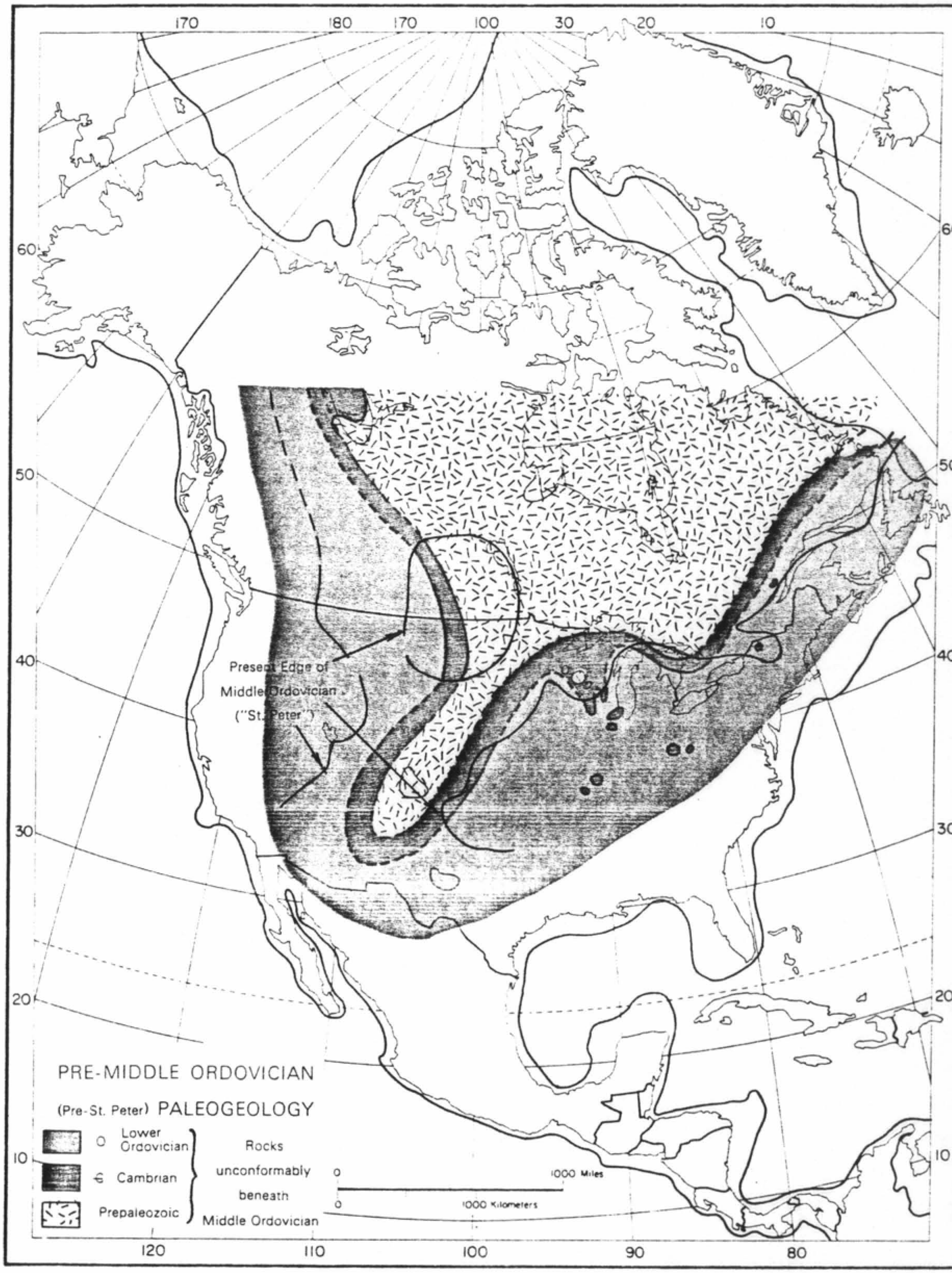

PRE-MIDDLE ORDOVICIAN
(Pre-St. Peter) PALEOGEOLOGY
O Lower Ordovician
Є Cambrian
Prepaleozoic
Rocks unconformably beneath Middle Ordovician
Present Edge of Middle Ordovician ("St. Peter")
0 1000 Miles
0 1000 Kilometers
120
110
100
90
80
60
50
40
30
20
10

Fig. 9

It is very widespread, composed of fine-medium, mature, quartz grains, redeposited from the center of the craton (Batten and Dott, 1981).

During the time following this (Chazy), erosion cut down through these older sediments as deep as Cambrian rocks. The resulting channels were filled by Glenwood shales (lower Chazy) and/or Ottawa carbonates, creating potentially ideal oil traps of truncated porous beds, covered by impermeable cap rocks. The St. Peter Sandstone is one such porous bed which pinches out updip to the west.

It is the Ottawa supergroup which consists of the Black River and Trenton Limestones. The deposition of these relatively pure carbonates lasted for several million years and is quite extensive. The deposition of these thin, uniform beds, traceable over such great distances, indicates a fairly stable craton. The depositional environment was apparently a shallow, well circulated, marine area as would be expected. Much fossil debris indicates a shelly facies or clastic nature (Batten and Dott, 1981). Estimates of past continental locations place North America much closer to the equator than at present. This more subtropical paleoclimate would be more consistent with the environments necessary for the deposition of highly fossiliferous carbonates and evaporites that are present.

Just as the bedrock dips southward, so do the overlying sediments. The Ottawa carbonates thicken southward from about 300 ft. in northern Illinois to 1400 ft. at the northern edge of the Mississippi embayment in northwestern Kentucky (Buschback, 1971). There is also a slight thinning westward as a result of minor uplift of the Indiana-Ohio platform, the Findlay and Waverly arches.

Isopachs on the Trenton show considerable variation in northwestern Ohio. The average thickness of the Ottawa here is 625 feet. It ranges from 475-650 ft. along an axis from Greenville, in Darke County, to Sandusky in Erie County; and 430-600 ft. from Georgetown, in Brown County, Indiana, to Columbus, in Franklin County (Stout, 1941). It ranges from 62 ft. in Fayette County, in eastern Indiana to 550 ft. in Lee County, Virginia (Calvert, 1962). Estimates of the Trenton alone, range from 60 feet in the southeast to 300 feet in the north, and increasing rapidly to the northwest (Stieglitz, in press). In past areas of production it is smaller, ranging between 150 and 300 feet (Stieglitz, 1981). Fig. 10 is an isopach map of northwestern Ohio.

The top of the Trenton Formation is a relatively flat surface, with fairly shallow irregularities, a few feet at the most. It is easily recognizable as well as mappable. Fig. 11 shows the structure on top of the Trenton in Ohio as well as surrounding areas. Fig. 12 shows the structure in the production area alone.

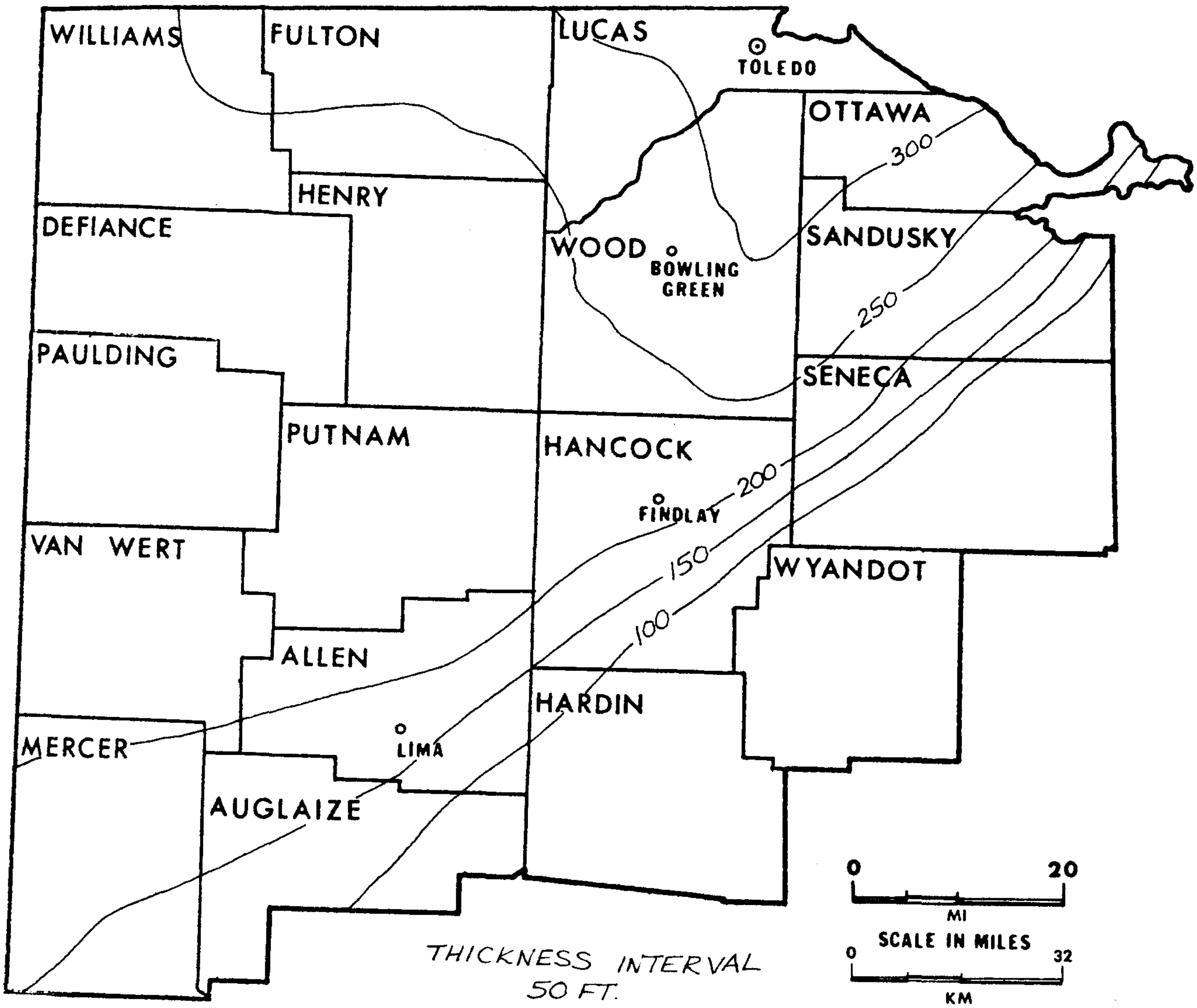
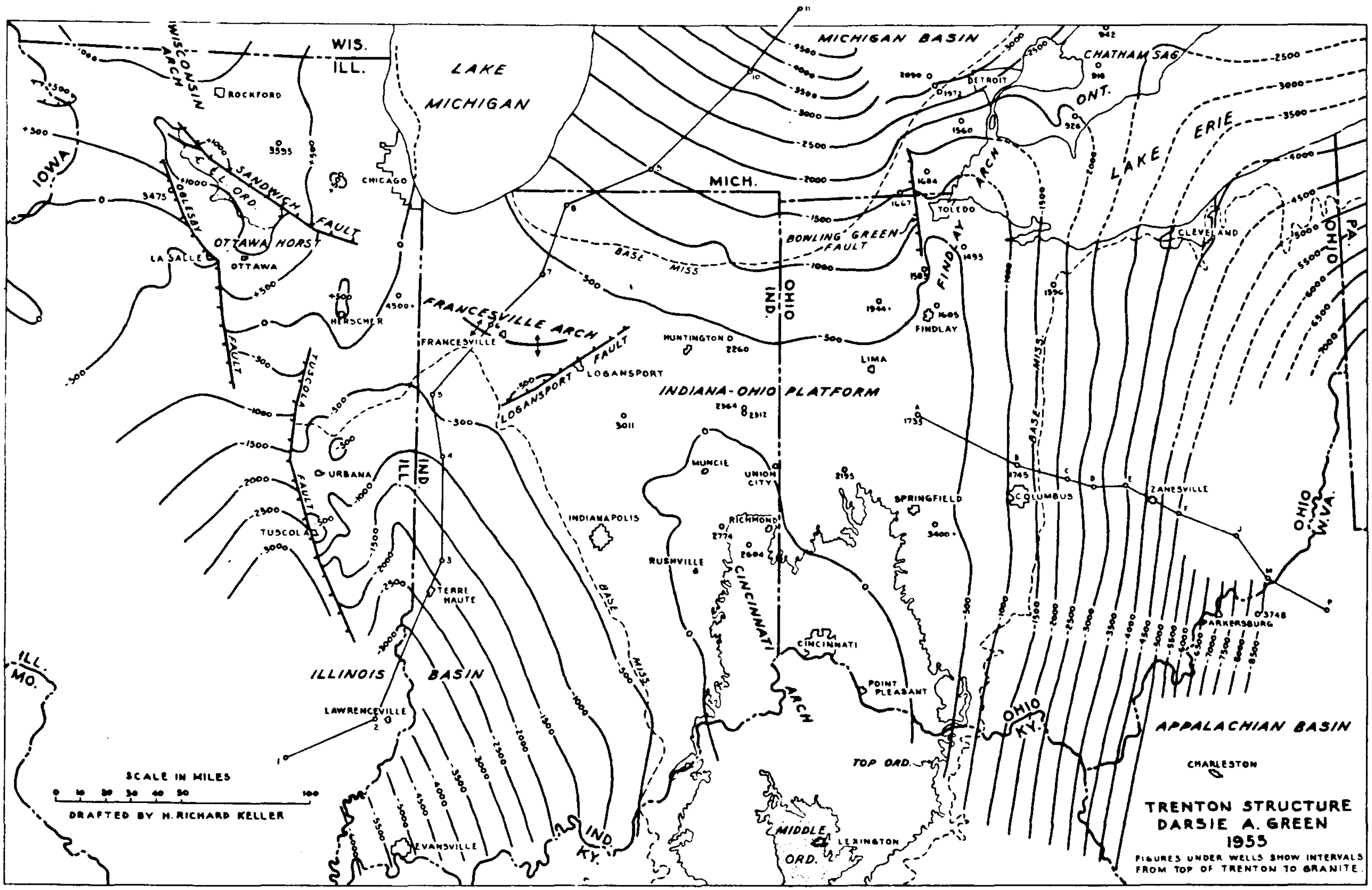

WILLIAMS
FULTON
LUCAS
TOLEDO
OTTAWA
HENRY
DEFIANCE
WOOD
BOWLING GREEN
SANDUSKY
PAULDING
SENECA
PUTNAM
HANCOCK
FINDLAY
VAN WERT
WYANDOT
ALLEN
HARDIN
MERCER
LIMA
AUGLAIZE
300
250
200
150
100
0
20
MI
SCALE IN MILES
0
32
KM
THICKNESS INTERVAL
50 FT.

Fig. 10



-Structure on top of Trenton limestone, contour interval 500 feet. In northern Illinois where Trenton is eroded, contours are projected by use of intervals from St. Peter and older formations. Locations of wells used in cross sections, limits of Mississippian, and intervals to granite are indicated.

Fig. 11

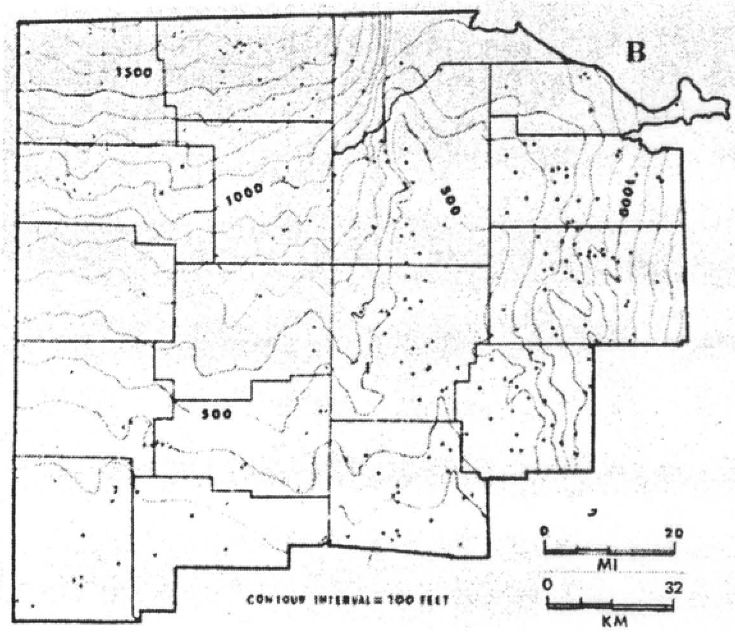


Fig. 12

As the map in Fig. 13 shows, the Trenton lies at fairly shallow depths in northwestern Ohio. Averaging 1300 feet in the production areas, it is deepest near the Michigan basin at 2600 feet, rising eastward to 1900 feet in north Ottawa County, and then gradually deepening again into the Appalachian basin.(Stieglitz, in press). Near the Bowling Green structure, in central Hancock and Wood Counties, it lies between 1050 and 1100 feet, and quickly deepens westward to 1700 feet in the western Wood County and toward the Illinois basin (Stieglitz, 1981). It outcrops in very few locations, most of them out of this state. It is, however, exposed along the Ohio river east of Cincinnati in Brown and Hamilton Counties.

The following deposition of the Trenton Formation, a broad area from the Findlay arch to the eastern edge of the Ozark dome, was raised and exposed to erosion (Rooney, 1966). As during all regressions, carbonates once stable are dissolved by solutions and altered to other forms. Landes (1970) feels

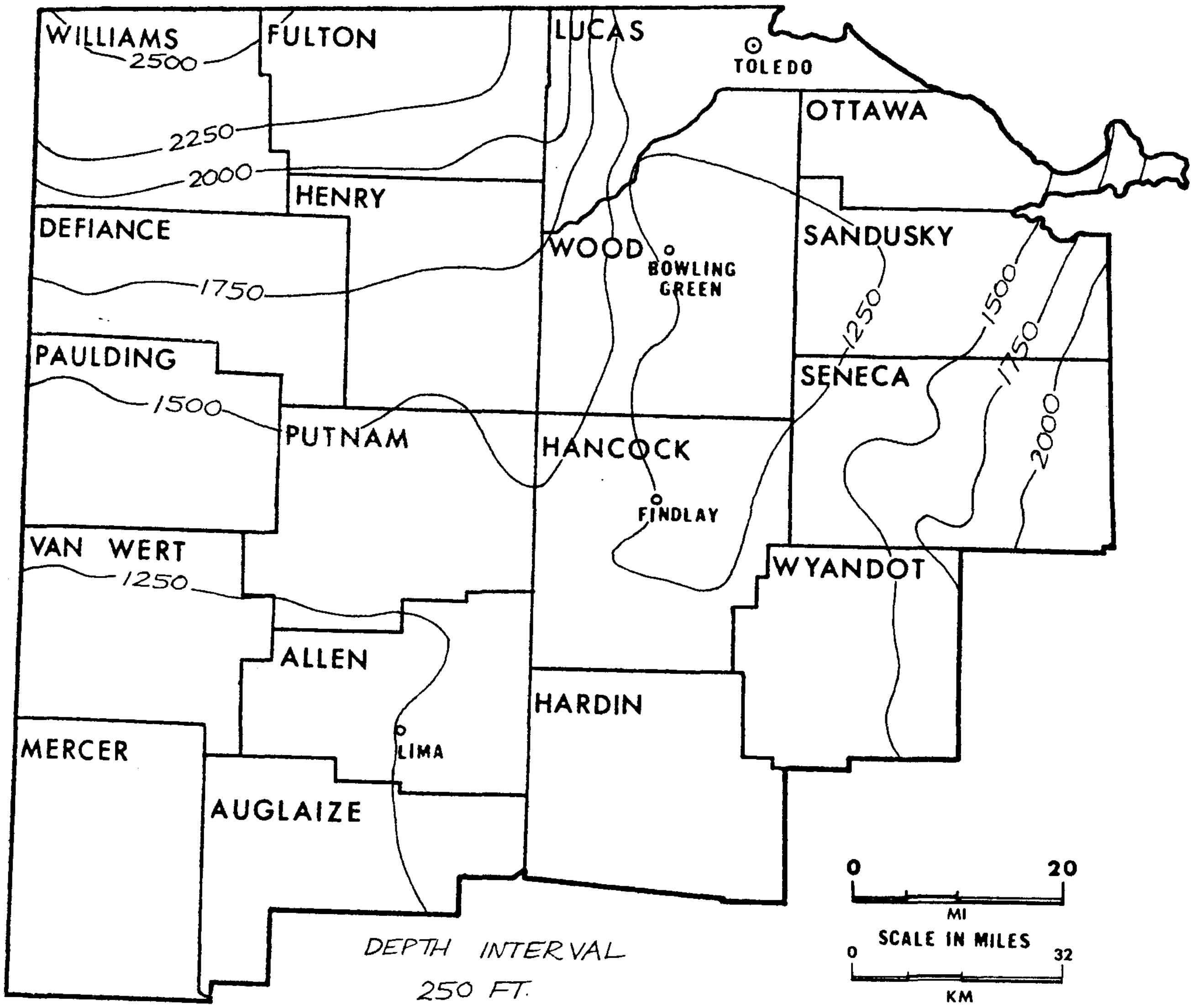

WILLIAMS
FULTON
LUCAS
TOLEDO
OTTAWA
2500
2250
2000
HENRY
DEFIANCE
WOOD
BOWLING GREEN
SANDUSKY
1750
PAULDING
1500
1250
1500
1750
SENECA
PUTNAM
HANCOCK
2000
FINDLAY
VAN WERT
1250
WYANDOT
ALLEN
HARDIN
LIMA
MERCER
AUGLAIZE
0
20
MI
SCALE IN MILES
0
32
KM
DEPTH INTERVAL
250 FT.

Fig. 13

that most of the dolotimization and further weathering of the Trenton in Ohio took place at this time. Fauna are also greatly affected during such times, and fossils are not as well preserved after alteration processes.

The start of the Cincinnati epoch, late Ordovician, was accompanied by another westward transgression of the epeiric waters. During this time, the Maquoketa supergroup was deposited, only to be partially eroded away at the end of the period. The Maquoketa includes the Cynthiana formation and the Utica Shale, and make up the impermeable rocks that overlie the Trenton. These cap rocks are chiefly dark shales, graywackes, and chert layers. Some volcanics are also present, which reflect the Taconic activity, and the developing continental margin to the east (Batten and Dott, 1981). Fig. 14 shows the extent of the late Ordovician deposits. Fig. 15 shows the paleogeography during that time, and the location of the equator should be noted. At this time Cincinnati arch was still not evident in Kentucky or Ohio (Buschback, 1971), although smaller components, the Findlay and Waverly arches, were already developed in Ohio, affecting overlying strata (Woodward, 1961).

Regression and erosion followed, and above this unconformity begins the Silurian period, the Hunton supergroup, and the Kaskaskia sequence. During Silurian time the Cincinnati arch began developing in Kentucky and Tennessee (Buschback, 1971). The Cincinnati arch was more of a barrier,

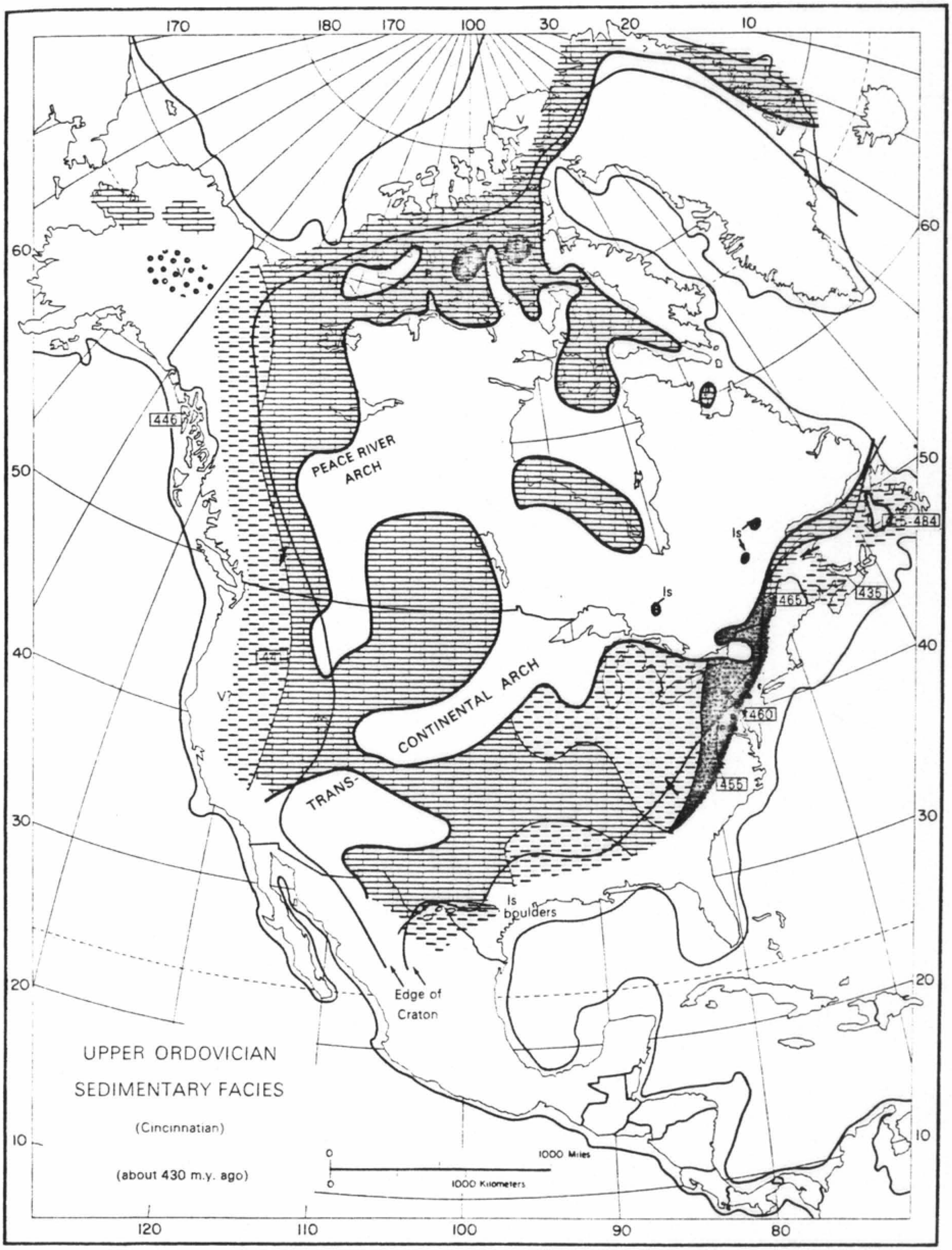

UPPER ORDOVICIAN
SEDIMENTARY FACIES
(Cincinnatian)
(about 430 m.y. ago)
PEACE RIVER ARCH
CONTINENTAL ARCH
TRANS-
Edge of Craton
ls boulders
ls
446
460
455
465
435
1000 Miles
1000 Kilometers

Fig. 14

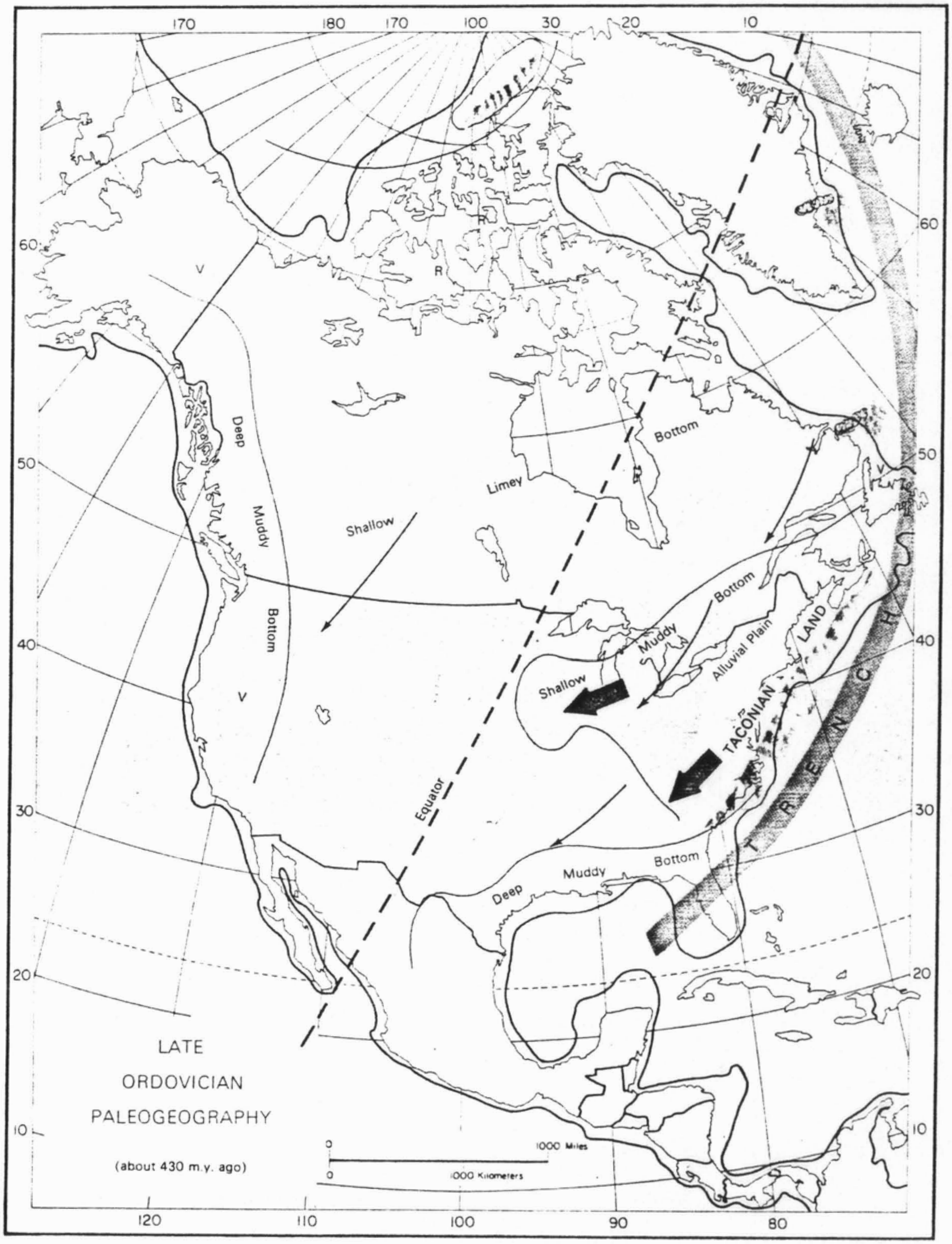

LATE
ORDOVICIAN
PALEOGEOGRAPHY
(about 430 m.y. ago)
Deep Muddy Bottom
Shallow
Limey
Bottom
Equator
Shallow
Muddy
Bottom
Alluvial Plain
TACONIAN
LAND
TRENCH
Deep Muddy Bottom
1000 Miles
1000 Kilometers

Fig. 15

serving as a hinge for the thickening wedge to the east than a supplier of sediment. The Michigan basin also deepened much during this period.

Silurian formations present in this section include the Medina Shale of the Alexandrian series, and the Clinton and Niagara Limestones of the Niagaran-Cayugan series. The latter is known for massive carbonate reefs,as well as periods of increased water depth due to reduced sedimentation. Very successful oil and gas production in the Clinton Formation has recently been developed in the northeast part of the state.

Regression accompanied emergence, and another unconformity was eroded on top of the uppermost Silurian. The Devonian rocks that follow are the youngest in the section, and include the basal Oriskany Sandstone and the Ohio Shale. Silurian, and especially Devonian strata, comprise little thickness in the subject area and along the arches.

DESCRIPTION AND COMPOSITION

The ability of the Trenton Formation to be a reservoir rock is in part due to its varying lithology; that is, its upper dolotimization. Much work has been spent analyzing its alteration features and its composition. A brief description is as follows.

The Trenton Formation generally consists of a fine to medium grained, buff-brown or lt. gray blue, slightly ferruginous, highly fossiliferous, clastic limestone. Its dense, impermeable, silt-sized matrix binds much pebble-sized limestone debris, including crinoids, brachiopods and bryozoa. Bedding is thin to massive. Environment of deposition was shallow-marine.

Upper parts of the Trenton have been irregularly altered to a coarsely crystalline dolomite, free of siliceous impurities. Thickness of these zones varies from a few feet to the Trenton's total thickness, approximately 600 feet. The dolomite is vugular and irregular, some larger vugs being lined with euhedral dolomite crystals (Buehner, 1971). This is responsible for locally good porousity. Permeability, however, is variable, limiting communication of zones. Contacts between the limestone and dolomite are sharp, field edges near vertical, and alteration doesn't appear outside the fields of production (Buehner, 1971). This may imply alteration along fractures and/or faulting.

Also present in the Trenton are thin, finely porous, calcareous shale partings, and very fine grained sand. These are not present in the dolotimized, producing areas.

Slightly differing lithologies are reported at both the uppermost and basal portions of the Trenton. Stieglitz (in press) describes the lowest beds as containing cherty, argillaceous and organic materials as well as some anhydrite. Some bentonite beds are also present. Rooney (1966) describes the upper feet of the Trenton as pitted, phosphatic and rubbly. A thin layer of angular chert fragments in highly ferruginous dolomite is present on top of the weathered zone. Traces of pyrite are also common and abundant in these upper beds. Such zones may represent changing environments which accompanied the deposition of different formations.

The Trenton differs from the underlying Black River Limestone in that it contains more insoluble residues, i.e., sand, shale, chert, and silicified fossils, while the Black River is a very fine-grained, lithographic, massive, microcrystalline limestone, with few fossils.

Analyses show quite noticeable distinctions between the composition of the dolomitic, producing rock and the otherwise impermeable, unaltered limestone. The upper, altered beds, mostly within 50 feet from the top of the formation, are only 50-60% limey, vs. the usually higher 80-90 percentages of calcium. This decreased limey nature is due to a higher magnesium composition. Orton (1888) reports the magnesium carbonate is greater than 23% in the productive fields. Pure dolomite is almost 46%.

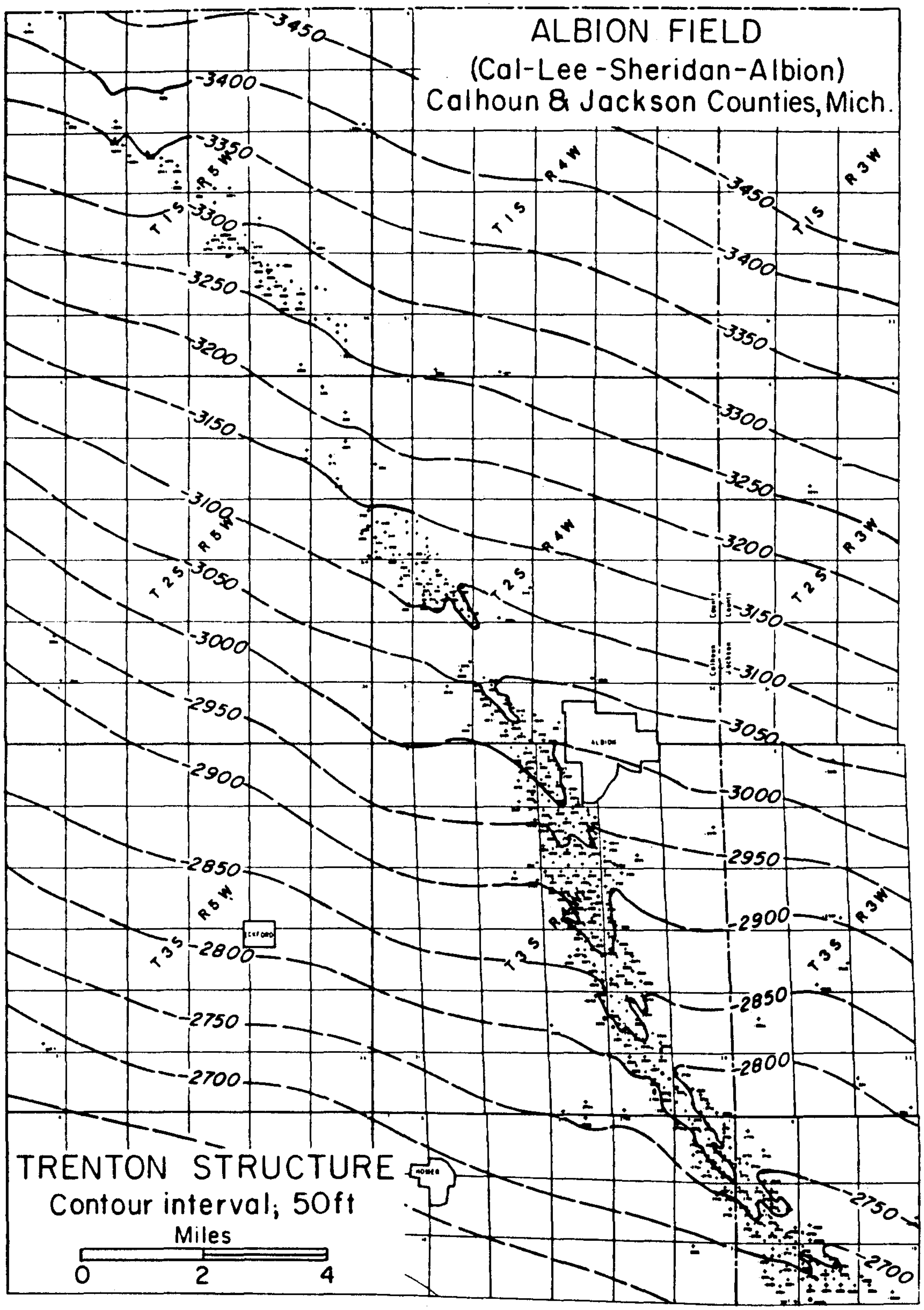
Bownocker (1903) sites these percentages:

	$CaCO_3$	$MgCO_3$	insol. residues	Al_2O_3 & Fe_2O_3
Findlay Gas Rk.	53.50	43.50	1.70	1.25
Bowling Green Gas Rk.	51.78	36.80	4.89	-
Lima Oil Rk.	55.90	38.85	.75	2.94

THE CAUSES AND EXTENT OF ALTERATION IN THE TRENTON

Dolomitization of the Trenton can be divided into two kinds. A large part was altered over a broad, shallow region, while a smaller percentage was centered around local fractures and joints. The Bowling Green area is an example of the latter, where alteration has gone deeper into the formation. Fractures here, as throughout Trenton, were probably partially caused by local tensions and stresses that developed as neighboring basins subsided (Woodward, 1961). Deeper seated faults may have also played a part. Buschback (1971) describes those near Bowling Green as a system of high-angle, possibly slip-strike faults and fractures. The main trend is north-west-southeast, with eastward protruding, complementary fractures. This region is quite similar to the Albion and Scipio fields of southern Michigan, which are also linear, dolotimized Trenton reservoirs. Figs. 16 and 17 show these fiads which were developed between 1959 and 1963, yielding almost 88 million barrels of oil and 94.5 million mcf of gas.

The causes of this dolomitization are also two-fold. Landes (1946) feels that solutions picked up greater amounts of magnesium as they ascended through



ALBION FIELD
(Cal-Lee-Sheridan-Albion)
Calhoun & Jackson Counties, Mich.
TRENTON STRUCTURE
Contour interval; 50ft
Miles
0
2
4
T1S
R5W
R4W
R3W
T2S
T3S
-3450
-3400
-3350
-3300
-3250
-3200
-3150
-3100
-3050
-3000
-2950
-2900
-2850
-2800
-2750
-2700

Fig. 16

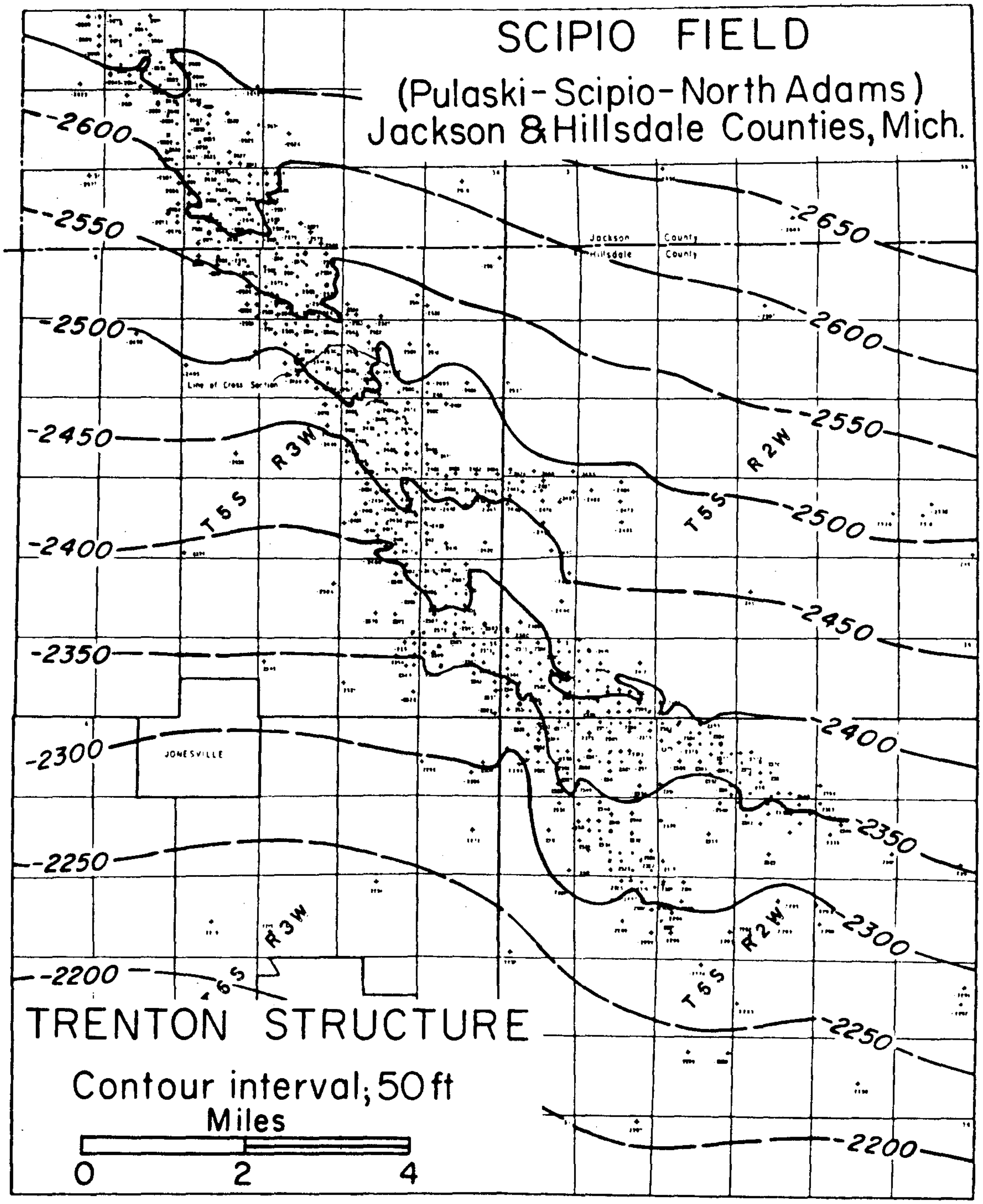
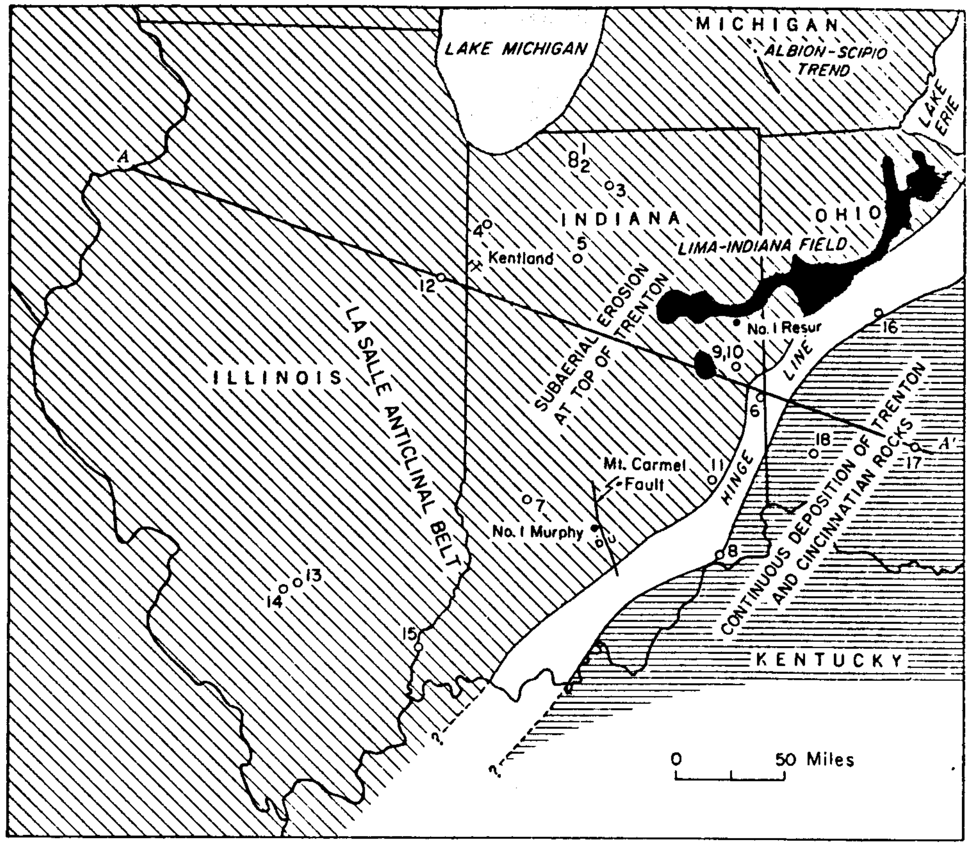

SCIPIO FIELD
(Pulaski-Scipio-North Adams)
Jackson & Hillsdale Counties, Mich.
TRENTON STRUCTURE
Contour interval; 50 ft
Miles
0 2 4
-2600
-2550
-2500
-2450
-2400
-2350
-2300
-2250
-2200
-2650
R3W
R2W
T5S
T6S
Jackson County
Hillsdale County
Line of Cross Section
JONESVILLE

Fig. 17

older dolomites, altering the younger limestones that eventually trapped them. Perhaps more of a cause was the solution, leaching, and weathering that took place after the emergence and subaerial erosion of the Trenton, following its deposition.

Rooney (1966) feels a distinct unconformity exists on top of the Trenton as a result. In addition to dolotimization, numerous crevices and honeycomb structures seem apparent on the upper surface. Drillers report hitting such openings, their bits dropping several feet at times. Some describe the surface as karst topography, where solution and weathering have dissolved cavities and enlarged previous cracks and holes. Such an irregular alteration is consistent with the variable permeability that exists, zones not connected forming larger pools of production.

Fig. 18 shows the area of exposure. Rooney (1966) feels that a hingeline running along the Findlay and Cincinnati arch regions separated the area of erosion to the west from the area of continued deposition to the southeast. It seems appropriate that the production zone lies in the exposed region where dolomitization would dominate. Dolomitization largely covers the following counties: Mercer, VanWert, Auglaize, Allen, Hancock, Wood, Sandusky, and Lucas. It partially covers these: Williams, Fulton, Henry, Defiance, Paulding, Putnam, Seneca, Ottawa, Hardin, and Wyandot.



MICHIGAN
LAKE MICHIGAN
ALBION-SCIPIO TREND
LAKE ERIE
A
INDIANA
OHIO
LIMA-INDIANA FIELD
Kentland
SUBAERIAL EROSION AT TOP OF TRENTON
No. 1 Resur
ILLINOIS
LA SALLE ANTICLINAL BELT
HINGE LINE
A'
Mt. Carmel Fault
No. 1 Murphy
CONTINUOUS DEPOSITION OF TRENTON AND CINCINNATIAN ROCKS
KENTUCKY
0
50 Miles

Fig. 18

OIL RECOVERY

Production potential in the Lima-Indiana field is far less than it was initially in the early 1900's. Buehner (1971) states that some fields have been discovered in the previously explored regions, although these haven't had much commercial significance. Most of the gas reserves have been depleted. In the hurry to remove the gas though, pressures decreased rather quickly and most of the oil wasn't removed, remaining in place. Unplugged, leaky wells, as well as ground water concerns, probably prevent adequate repressurization of the area, which may hold 60% or more of the original reserves (Stieglitz, 1981). It is such oil that makes up the probable targets for future drilling operations. These will be through discoveries of new production areas or improved recovery methods.

In the past, oil was produced primarily from a zone 20 to 25 feet thick within the upper 50 feet, and later, to a lesser extent from deeper zones associated with fractures, such as Bowling Green (Coogan and Maxey, 1982). With continued testing and uses of geophysics and other modern sub-surface techniques, deeper pay zones may be discovered. The Trenton is actually fairly recognizable through electric logging methods. The lower, unaltered sections yield higher sonic velocities, resistivities, neutron responses, and negative self-potentials; lower gamma radioactivity, as compared to more porous, altered zones and overlying Maquoketa shales (Atherton and others, 1964).

Although most of the hydrocarbons lie in stratigraphic traps of some kind, Stieglitz (in press) distinguishes these as follows. 1) Structural closures on top of the Trenton where it crosses the broad anticlines of nearby arches. 2) Fracture zones, similar to the Albion-Scipio fields such as is found near Bowling Green. 3) Updip facies changes into the Utica Shale, and between dolomite and limestone within the formation. 4) And lastly, areas of nosing and terracing that may be present in the Trenton. These locations provide settings for more subtle, undiscovered traps, if they exist. Improved stimulation methods, as well as production techniques unknown to past drillers, may greatly improve yields.

Current figures do show steadily increasing drilling projects in the state; permits up to 12,547 in 1981, compared to 5820 in 1978 (Gannan, 1982). Costs play a major role in this, and as oil prices increase, reserves once unprofitable to produce become more reasonable.

Possibly of greater potential are secondary and tertiary recovery methods of mining and draining such as Stieglitz (1981) discusses. Such mining currently seems to be the most economical possibility, where shallowness would allow much lower drilling and mining costs. It's past productivity and competent surrounding stratigraphy to support shafts also favor such projects.(Stieglitz, 1981). Removal of Black River Limestone could be used in the lime industry to help offset costs. In conclusion, it seems further analysis of the area, and continued testing, would not be wasted effort, and could possibly prove quite profitable.

PICTURE CREDITS

Fig. 1	Summary of new oil and gas well drilling by producing zones - 1981 (Ohio Dept. of Natural Resources)
Fig. 2	Location map of northwestern Ohio (Stieglitz, 1981, Fig. 1, p. 527)
Fig. 3	Ordovician production, Ottawa (Buehner, 1971, Fig. 2, p. 38)
Fig. 4	Trenton oil production from northwestern Ohio (U.S. Geological Survey)
Fig. 5	Structural features of the Eastern Interior Region (Buschback, 1971, Fig. 1, p.22)
Fig. 6	Depths to Precambrian basement in Ohio (Clifford, 1975, Fig. 2, p. 3)
Fig. 7	Stratigraphic column by Gary Mitiska
Fig. 8	Structure on top of the Sauk Sequence (Calvert, 1962, Fig. 6, p. 10)
Fig. 9	Pre-middle Ordovician Paleogeology (Batten and Dott, 1981, Fig. 12.3, p.258)
Fig.10	Thickness of Trenton Formation (Stieglitz, 1981, Fig. 2C, p. 528)
Fig.11	Generalized structure on top of Trenton Formation (Stieglitz, 1981, Fig. 2B, p. 528)
Fig.12	Trenton Structure (Green, 1957, Fig. 1)
Fig.13	Depth to top of Trenton Formation (Stieglitz, 1981, Fig. 2D, p. 528)

Fig. 14 Upper Ordovician Sedimentary Facies (Batten and Dott, 1981, Fig. 12.7, p. 261)

Fig. 15 Late Ordovician Paleogeography (Batten and Dott, 1981, Fig. 12.8, p. 262)

Fig. 16 Trenton Structure of Albion Field, Michigan (Buehner, 1971, Fig. 3, p. 39)

Fig. 17 Trenton Structure of Scipio Field, Michigan (Buehner, 1971, Fig. 4, p. 40)

Fig. 18 Unconformity at top of Trenton Limestone (Rooney, 1966, Fig. 1, p. 534)

REFERENCES CITED and BIBLIOGRAPHY

Alkire, R.L., 1951, Oil and Gas Production, History, Regulation, Secondary Recovery and Bibliography: Ohio Geologic Survey Report of Investigations 8, pt. 2, 95 p.

Atherton, E., Bell, A.H., Buschback, T.C., and Swann, D.H., 1964, Deep Oil Possibilities of The Illinois Basin: Illinois State Geological Survey Circular 368.

Batten, R.L. and Dott, R.H., Jr., 1981, Evolution of The Earth, p. 229 - 278.

Bownocker, J.A., 1903, The Occurrence and Exploitation of Petroleum and Natural Gas in Ohio: Ohio Geol. Survey, Ser. 4, Bull. 1, 325 p.

Bristol, H.M. and Buschback, T.C., 1973, Ordovician Galena Group (Trenton) of Illinois - Structure and Oil Fields: Illinois State Geol. Survey, Ill. Petroleum 99.

Buehner, J.H., 1971, Future Oil and Gas Production of The Cincinnati Arch - North Illinois State Geol. Survey, Ill. Petroleum 95, p. 35 - 43.

Buschback, T.C., 1971, Background Materials For Symposium on Future Petroleum Potential of NPC Region 9 (Illinois Basin, Cincinnati Arch, and Mississippi Embayment): Illinois State Geol. Survey, Ill. Petroleum 96.

Calvert, W.L., 1962, Sub-Trenton Rocks From Lee County, Virginia to Fayette County, Ohio: Ohio Geol. Survey Report of Inv. 45, 57 p.

------------- 1964, Summary of Oil and Gas Activity in Ohio During 1963: Ohio Geol. Survey Report of Inv. 56.

Carmen, J.E., and Stout, W., 1934, Relation of Accumulation of Oil to Structure and Porousity In The Lima-Indiana Field: American Association of Petroleum Geologists; Problems of Petroleum Geology, p. 521-529.

Clifford, M.J., 1975, Preliminary Report on Potential Hydrocarbon Reserves Underlying The Ohio Portion of Lake Erie, Ohio Dept. of Natural Resources, Div. of Geol. Survey, Geol. Note 1.

Cohee, G., 1948, Cambrian and Ordovician Rocks in Michigan Basin and Adjoining Areas: Am. Assoc. of Petro. Geol. Bull., v 32, p. 1417-1448.

Coogan, A.H., and Maxey, M.M., 1982, Oil and Gas Occurrence In The Trenton Limestone Reservoir, Northwestern Ohio, Kent St. University.

Fettke, C.R., 1948, Subsurface Trenton and Sub-Trenton Rocks in Ohio, New York, Pennsylvania, and West Virginia: Am. Assoc. of Petroleum Geol. Bull., v.32, p. 1457-1492.

Gannan, L., 1982, Despite Lessening Consumption, Petroleum Search By Independents Expands In 1981 - Annual Review: Northeast Oil Reporter.

Green, D.A., 1957, Trenton Structure in Ohio, Indiana, and Northern Illinois: Am. Assoc. of Petroleum Geol. Bull, v.41, p. 627-642.

Landes,K.K., 1946, Porousity Through Dolomitazation: Am. Assoc. of Petroleum Geol. Bull., v.30, p. 305-318.

Orton, E., 1888, The Trenton Limestone As A Source of Oil and Gas in Ohio: Ohio Geol. Survey Report, v.6, p. 101-310.

---------- 1890, Origin of The Rock Pressure of Natural Gas in The Trenton Limestone of Ohio and Indiana: Geol. Society of Am. Bull. 1.

Rooney, L.F., 1966, Evidence of Unconformity At The Top of Trenton Limestone in Indiana and Adjacent States: Am. Assoc. of Petroleum Geologists Bull., v.50, p. 533-546.

Rummerfield, B.F., and Morrisey, N.S., 1971, A Review of Past Results and Future Potentials of Using Geophysics in NPC 9: Illinois State Geol. Survey, Ill. Petroleum 95, p. 12-14.

Shearrow, G.G., 1955, An Old Pay With A Future (Part 2), Where The Trenton Produces in Ohio: Oil and Gas Journal, v. 54, no. 9, p. 157.

-------------- 1957, Geologic Cross Section of The Paleozoic Rocks From Northwestern To Southwestern Ohio: Ohio Geol. Survey Report of Inv. 33, 42p.

Stieglitz, R.D., 1975, Sparry White Dolomite and Porousity in Trenton Limestone (Middle Ordovician) of Northwestern Ohio: Am. Assoc. of Petroleum Geol. Bull., v. 59, p. 530-533.

Stieglitz, R.D., 1981, Trenton Formation (Middle Ordovician) of Northwestern Ohio: Possible Target For Petroleum Mining: Am. Assoc. of Petroleum Geol. Bull., v. 65, p. 526-530.

--------------- In Press, The Trenton Formation (Ordovician) of Northwestern Ohio: Ohio Geol. Survey.

Stout, W., 1947, Generalized Section of Rocks in Ohio: Ohio Geol. Survey Info. Circular, Ser. 4, No. 4.

Vandenberg, J., 1979, Petroleum Industry in Illinois, Oil and Gas Developments: Illinois Institute of Natural Resources, State Geol. Survey Div. 120.

Vanuxem, L., 1838, Of So Much of The Geologic Survey of The Third District of The State of New York as Relates To Objects of Immediate Utility, In Second Annual Report: New York Geol. Survey, p. 253-286.

Verweibe, W.A., 1929, Unconformity on Top of Trenton in Lima-Indiana District: Am. Assoc. of Petroleum Geol. Bull., v. 13, p. 688-689.

Wasson, I.B., 1932, Sub-Trenton Formations in Ohio: Journal of Geology, v. 40, No. 8, p. 673-687.

Woodward, H.P., 1961, Preliminary Subsurface Study of Southeastern Appalachian Interior Plateau: Am. Assoc. of Petroleum Geol. Bull., v. 45, p. 1634-1655.